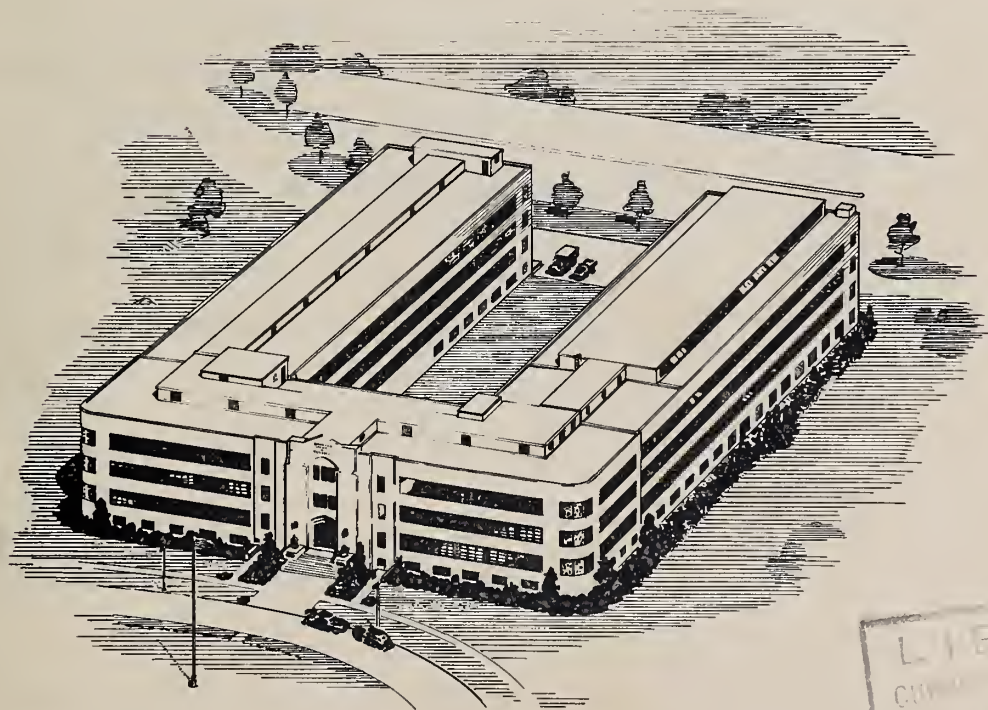
UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Administration
Bureau of Agricultural and Industrial Chemistry

OIL FIRING FOR THE MAPLE SIRUP EVAPORATOR

G. W. Macpherson Phillips and Richard P. Homiller



Eastern Regional Research Laboratory
Philadelphia 18, Pennsylvania.

JUNE 1953

AIC-358

CONTENTS

Page

SUMMARY

INTRODUCTION 1

Advantages of oil as fuel 1

EQUIPMENT FOR OIL BURNER 2

Adaptation to an existing evaporator 2

Experiments at the Eastern Regional Research Laboratory 2

Design of the arch 3

Choice of an oil burner 5

Oil storage 6

CONTINUOUS SIRUP DRAW-OFF 6

COSTS 7

Cost of equipment 7

Cost of operation 7

LITERATURE REFERENCES 10

SUMMARY

Use of oil instead of wood as fuel for maple sirup evaporators has advantages aside from the cost. It eliminates fluctuations in rate of evaporation making control of sirup density easier, and producing more uniform and better quality sirup. Under favorable conditions, continuous sirup draw-off may be possible. Use of oil saves much labor in the sugar-house as well as in the wood lot. Under average conditions, the total costs of the fuels are about the same. If wood is valuable and labor scarce, oil will be cheaper, and vice versa.

OIL FIRING FOR THE MAPLE SIRUP EVAPORATOR

G. W. Macpherson Phillips and Richard P. Homiller

Eastern Regional Research Laboratory
Philadelphia 18, Pennsylvania

INTRODUCTION

The use of oil instead of wood as fuel for maple sirup evaporators can be considered from two angles - quality of sirup produced and cost of operation. The steady hot oil fire boils the sap more uniformly and usually faster, thus better and more uniform sirup can be made. The cost of operation may be less or greater than with wood, according to local conditions. This publication gives recommendations on oil-burning evaporators. These are based partly on general principles and partly on the results obtained in investigations at the Eastern Regional Research Laboratory on a small evaporator of standard design, to which an oil burner and a special arch had been fitted. The amount of oil needed to evaporate a gallon of sap was determined, and some of the other aspects of using oil as fuel were studied.

Advantages of Oil as Fuel: Aside from eliminating the labor of handling the wood and firing the evaporator, most of the advantages of burning oil are based on the constant steady heat of the oil fire. This steady heat makes it much easier to control the operation of the pans and to produce sirup of uniform quality as well as to predict exactly how much sap can be handled each day. One man alone, without help, should be able to take care of all the operations in a sugarhouse equipped with an oil-burning evaporator. With the fluctuating heat of a wood fire, it is practically impossible to draw off sirup from the evaporator continuously; therefore the sirup must be boiled down to exact density in batches. With oil firing, the intensity of the fire remains constant hour after hour, once the furnace is well heated up. Thus if a steady and uniform stream of sap is fed into the pan, it should be possible to draw off sirup at a uniform rate and at a fairly uniform density. To do this, a special arrangement of draw-off valve is necessary, and considerable practice in carefully adjusting the valve is needed, particularly with smaller evaporators. This operation, together with the instruments needed, is discussed later in the paper.

The experiments described here indicate that an evaporator equipped to burn oil may be expected to evaporate more sap than a wood-burning one of the same size. Thus the sap would remain a shorter time in the evaporator, and the sirup would consequently be lighter in color. Data on the formation of color during evaporation of sap have been obtained by C. O. Willits and co-workers (5).

Another advantage of burning oil is that the accumulation of soot on the bottom and the flues of the pan will be, if the flame is properly adjusted, much less than occurs with wood firing. And of course with oil there are no ashes.

EQUIPMENT FOR OIL BURNING

Adaptation to an Existing Evaporator. The evaporator used in these investigations was the standard design of George H. Soule Company[1], in which the sirup pan is over the fire and the sap pan is at the rear. The total size is 2' - 6" by 8' - 0", giving 20 square feet of horizontal area. There are deep narrow flues in the sap pan, increasing the total heating surface to 85 square feet. Its rated evaporative capacity is 50 gallons of sap per hour; with sap containing 2.00 percent sugar (2.00° Brix) this is equivalent to evaporating 48.8 gallons of water per hour, or with sap of 3.00 percent sugar, 48.3 gallons of water. The accurate measure of the performance of an evaporator is of course the amount of water it evaporates out of the sap, though for practical purposes the amount of sap handled is a good enough figure for comparison. The amount of sirup produced per gallon of sap evaporated is almost in direct proportion of the sugar content of the sap, hence sirup production is misleading as a standard of comparison of evaporation performed.

For the first tests, only the front end of the furnace was altered. The cast-iron front and grates were removed and a brick front wall was built 5 inches farther forward to increase slightly the inside length of the firebox. Figure 1 shows the apparatus as it would appear if the right-hand wall of the whole arch and pan were removed. Figure 3 is a view taken as if looking at the front wall from inside the firebox. Figure 4 is similarly a cross section cut across the flues and looking toward the chimney. With the arch built in this way, it was not possible to obtain proper boiling in the sap pan; a rolling boil was obtained in only a small portion of it, at the front end. Then the rear end of the firebox was altered; its rear wall was moved back 5 inches and its height was reduced to increase the areas of direct heat radiation from the fire to the bottom of the rear pan. These changes are shown in Figure 2; the dotted arrows illustrate the line of sight from fire to pan. The views as seen in Figures 3 and 4 remain the same. With this arrangement, the sap pan boiled better; a rolling boil was obtained at least half way back in the sap pan.

Experiments at the Eastern Regional Research Laboratory. In the evaporator arch modified as described above, an oil burner of experimental type was installed (Figure 5). To study the effects of different rates of burning oil under this evaporator, a burner adjustable to any rate between 1-1/2 and 8 gallons per hour was chosen. Various experimental tanks and instruments were installed, as shown in Figure 5. Thermocouples measured the temperatures of the sap at seven places in the pans and a recording instrument "B" printed these temperatures on a large strip chart. The sap level in the pan was kept constant by the usual type of float regulator. Sap flowed to the regulator from a small feed tank "C", which was kept full by pumping into it sap from the supply tank "D" and permitting the overflow to return to the supply tank. This supply tank was mounted on scales "E", and the time taken

[1] MENTION OF SPECIFIC PRODUCTS IN THIS PAPER IS NOT TO BE CONSTRUED AS A RECOMMENDATION OR ENDORSEMENT BY THE DEPARTMENT OF AGRICULTURE OVER SIMILAR PRODUCTS NOT MENTIONED.

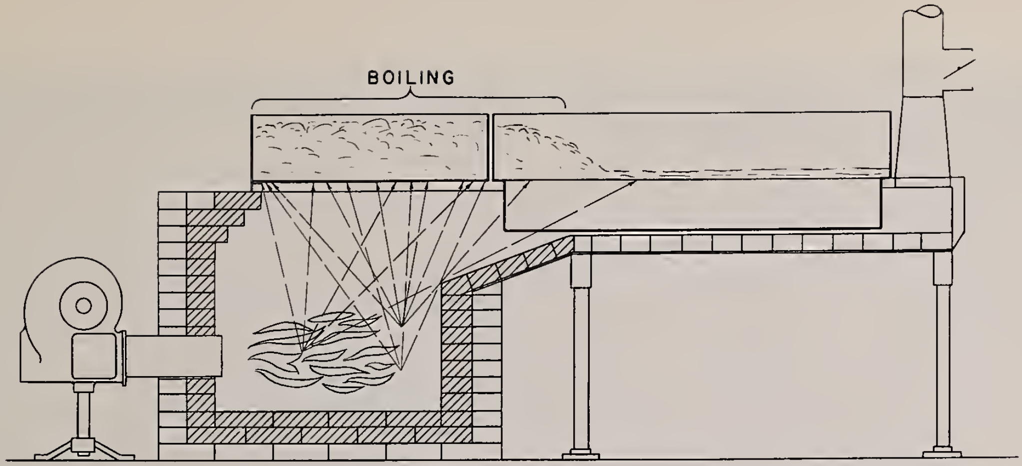


FIGURE I. OIL BURNING FURNACE WITH ORIGINAL BACK WALL

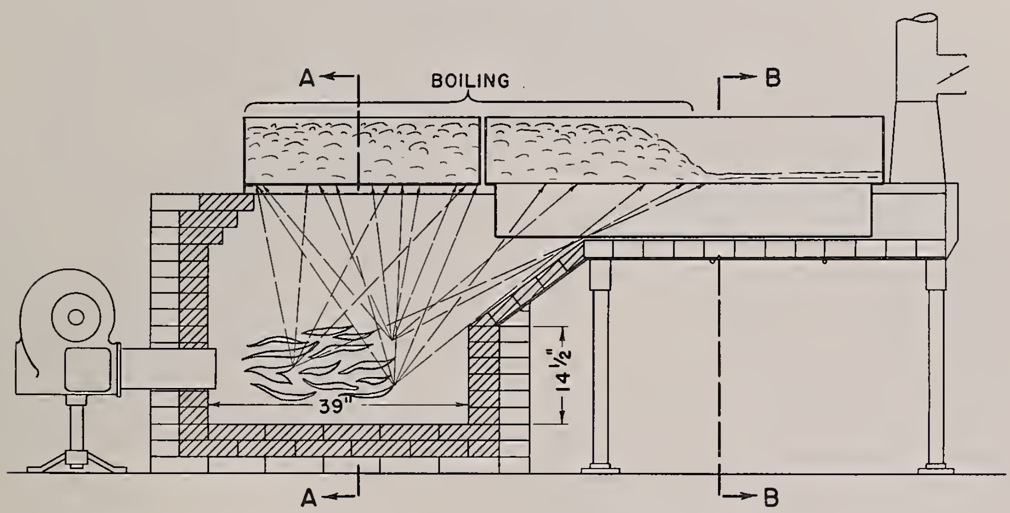


FIGURE 2. OIL BURNING FURNACE WITH IMPROVED BACK WALL

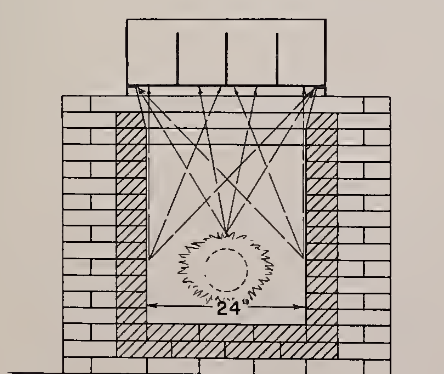


FIGURE 3.
SECTION ON LINE A-A

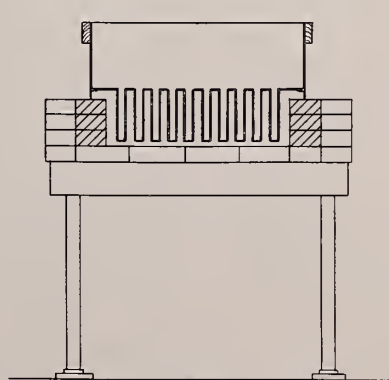


FIGURE 4.
SECTION ON LINE B-B

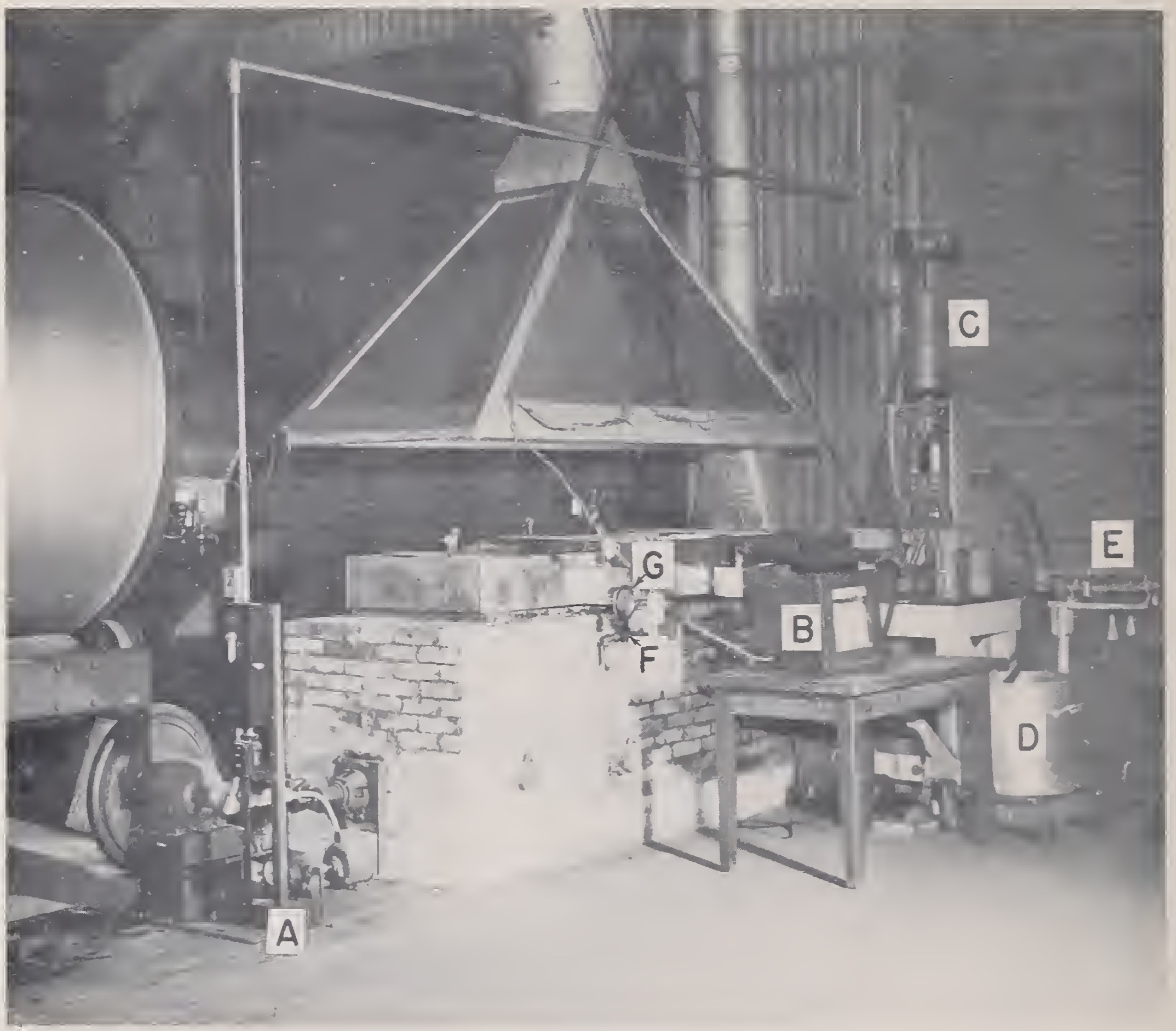


Figure 5. Experimental oil-burning evaporator.

A Oil burner, experimental type.

B Temperature recorder.

C Sap feeding tank, constant level.

D Sap storage tank.

E Scale, weighing the storage tank.

F Syrup drawoff valve.

G Syrup thermometer.

by the evaporator to draw each successive 20 pounds of sap was signalled by an electric contact on the scale beam. The sirup was drawn off continuously through a hand-adjusted valve. The amount drawn off, and the oil used by the burner, were also weighed frequently. Since maple sap is available for only a short time each year, sugar solutions were used in the preliminary experiments, and maple sap was used for the later runs only. Both the sugar solutions and the sap contained about 3 percent sugar. Oil-burning rates as low as 2-1/2 gallons per hour and as high as 6-1/2 were obtained. A sap-evaporating rate of 65 gallons per hour was reached, which is 30 percent more than the manufactured rating for this evaporator. This is an important point, because shorter time in the evaporator makes sirup of lighter color. The fuel efficiency was good. Even though the liquids entered the pan at temperatures of 32° to 40° F., in most of the runs the sap evaporated ranged from 9-1/2 to 10-1/2 gallons per gallon of oil.

Design of the Arch: The design of an arch for oil burning (including fire-box and flue space) is based on certain fundamental engineering principles, as outlined below.

(1) Pan surfaces which can "see" a yellow or white flame or glowing brick obtain far more heat by direct radiation than they do by contact with the hot gases. Therefore the whole furnace should be so designed that as much as possible of the pan bottom can "see" the flame or the red-hot brickwork, and as much as possible of the flame and hot brick can "see" the pan bottom.

(2) The amount of radiated heat received by any surface is proportional to its "projected" area, not its actual surface area. That is, if you imagine a certain spot in the flame to be your eye, and you look in various directions, as shown by any one set of dotted arrows in Figure 2, any certain portion of the pan will be receiving from that spot of flame an amount of radiant heat proportional to its apparent area as you would see it. Thus there is no great advantage in having corrugations or deep channels (so-called "flues") in those parts of the pan that "see" the flame or the red-hot brickwork, since these do not increase the projected area. Such flues would of course give some increase in evaporating capacity, but not in proportion to the amount of metal surface added. Furthermore, there is the possibility of burning out the bottom of the channels if sugar sand should accumulate there and permit the formation of caramel or a dry pocket.

(3) Deep channels are, however, highly desirable in the rear pan, beyond the "sight" of the furnace, because there the only way heat is transmitted to the metal is by direct contact with the hot gases. Every square foot of metal that projects into the stream of gases is effective in absorbing heat from them. High efficiency, that is, high economy in utilization of the heat in the fuel, resulting in low fuel cost per gallon of sap handled, cannot be obtained if the gases are discarded to the chimney at high temperature. Thus a large metal surface of deep juice channels is desirable in the rear pan to cool the gases after they leave the hot radiation zone.

(4) For best combustion, the flame should nearly but not quite touch the rear wall of the firebox. This is the best condition for complete vaporizations of the oil droplets. No flame should touch any part of the pans or enter the flue passages, because when a yellow flame touches a metal surface kept below red heat the flame becomes chilled and deposits soot.

(5) The floor and all four sides of the firebox should be lined with insulating brick. When the fire is started the inner surface of such brick heats up many times as fast as would ordinary firebrick, thus bringing the inside surfaces of the firebox quickly up to proper operating temperature for good radiation and for complete vaporization of the oil. Most commercial oil burners do a good job of atomizing the oil, but occasionally throw a few droplets of imperfectly atomized oil. Until the brick surface gets red hot, these droplets pass into the flue passages, causing flame there and consequently depositing soot, but as soon as the surface of the brick becomes red hot, the droplets are vaporized by heat radiated from the brick. The choice of brick to be used is to some extent a compromise between high insulating value and long life. In general, the better the insulating quality of a brick, the greater is its tendency to spall or disintegrate at high temperature. In these experiments a brand known as JM-20, which is stated to withstand a furnace temperature of 2000° F., has given satisfactory service. A well-built furnace should last for years.

This type of brick also greatly reduces loss of heat through the walls of the firebox. It cannot be used in a wood-burning firebox because it is too soft and fragile to stand the battering of the wood thrown in.

To provide sufficient space for complete combustion of the oil and so prevent the flame from touching the pan, the grates should be removed and the floor of the firebox constructed on the bottom of the ashpit. The recommendations of the manufacturer of the particular burner used should be followed as to the dimensions of the firebox and the height of the burner above the floor of the firebox. The consensus of most oil-burner manufacturers is that the total volume of the part of the firebox that acts as a combustion chamber should be about 1 cubic foot for each gallon of oil burner per hour. In a firebox of the shape shown here, which has a low vertical back wall opposite the burner and a long slanting surface continuing this wall, the best practice is to count as combustion chamber only that part of the firebox which is below the level of the top of the vertical back wall. In the firebox described here (Figures 2 and 3) this is a rectangular space 39 inches long, 24 inches wide, and 14-1/2 inches high, or 7.8 cubic feet.

The dotted arrows in Figures 1, 2 and 3 show the extent of the lines of direct radiation of heat from various typical parts of the flame and of the red-hot brick. All parts that are equally hot throw off heat at the same rate, and equally in all directions. Whatever part of the pan metal is reached by these "lines of sight" will receive much more heat than the parts not "seen" by the flame or the red-hot brick. The fact that a part of the length of the deep juice channels, or "flues", projects into the zone of radiation is an accidental circumstance caused by the modifications made to this particular evaporator; it is not intended to be a recommendation. The

pan was already made with these channels, and when the firebox was lengthened they simply remained. As already explained, it is not of much use to have deep channels in the radiation zone, though they are highly desirable, for oil as well as for wood burning, in the rear part beyond the radiation zone.

Choice of an Oil Burner: In these investigations, a special burner capable of being adjusted to give widely different rates of oil-burning was used. This is not necessary in an ordinary sugarhouse. A standard electric motor-driven burner of the type used for house-heating is suitable, for there is no need to alter or adjust the heat while the burner is operating. This type of burner uses No. 2 oil, which is easily obtainable. It can be purchased through a heating contractor and serviced by him. It consists of an oil pump and an air blower, both driven by one motor, a nozzle for atomizing the oil, and a mixing head, which mixes the air and the atomized oil and blows them into the firebox. These burners are usually manufactured in three or four standard models; each model can be fitted with several optional sizes of oil nozzle. Furthermore, the oil delivered by any nozzle can be altered through a small range by adjusting the oil pressure at the pump. Thus the exact rate of oil burning desired can be chosen, and if after installation it appears that a different oil rate would suit that particular evaporator better, a new oil nozzle can be substituted at small expense. For instance, one typical manufacturer sells two models of suitable size for maple evaporators. The smaller of the two has a 1/6-horsepower motor, and can be fitted with nozzles of any capactiy between 5 and 8 gallons of oil per hour, suitable for evaporating 50 to 80 gallons of sap per hour. The larger one has a 1/4-horsepower motor, and can be fitted for capacities from 10 to 20 gallons of oil per hour to evaporate 100 to 200 gallons of sap per hour. For evaporators with a capacity of more than 200 gallons of sap per hour, two burners can be installed, each with its own motor.

The "industrial" type of oil burner, equipped to burn the heavier and cheaper grades of oil (No. 5 or No. 6), are in general not desirable for maple sap evaporators even though No. 5 oil costs only about 8-1/2 cents a gallon instead of 13 cents. They cost far more than the domestic type, are of more complicated construction and are more difficult to operate and service. Standard No. 6 oil, the cheapest grade, must be heated before burning (usually by an electric heater installed at the burner), which adds considerably to the trouble of operation. No. 5 oil, which is the next grade below No. 2, is supposed to be burnable without heating, but this is not always true; and certainly in the cold weather of the maple season it would not be safe to try to burn No. 5 oil without heating. All in all, it is better to burn the more expensive No. 2 oil and use the domestic type of burner even if two burners have to be used for a large evaporator.

By using a high burning rate, it will usually be possible to force an evaporator to handle somewhat more than the capacity for which it is rated with wood firing. This tends to produce lighter sirup because of the shorter time that the sap and sirup stay inthe pan. Although different sizes and designs of evaporators may have different fuel efficiencies, an oil burner may be selected on the assumption that oil burning will increase the capaci-

ty of an evaporator by 30 percent, and that 1 gallon of oil will evaporate approximately 10 gallons of sap to sirup. Thus an evaporator rated to handle 100 gallons of sap per hour when burning wood may be considered to have a rating of 130 gallons when burning oil, and a burner rated at 13 gallons of oil per hour may be installed. These ratios are not necessarily exact for all makes and all sizes of evaporators.

Oil Storage: Because the sap season is so short and in many localities delivery of oil during the season would be difficult, it may be desirable to install a storage tank large enough to contain the entire season's supply of oil. For instance, for a sugarbush which expects a total crop of 20,000 gallons of sap in its best year, a 2,000-gallon oil tank would be barely large enough, and a 2200-gallon tank would be safer. Pamphlets Nos. 31 and 58 of the National Board of Fire Underwriters give standards of safety for the installation of oil tanks and burners.

CONTINUOUS SIRUP DRAW-OFF

As previously stated, under favorable conditions and with suitable equipment, use of oil instead of wood may make it possible to draw off the sirup in a continuous stream rather than in batches. To accomplish this the evaporator and its accessories must be just right, and a good deal of care and practice in adjusting the valve will be needed. If successful, the operator will be relieved of the labor of finishing off each batch separately, and will have more time to spend on filtering, canning and other chores involved in making sirup.

For an evaporator to be operated with continuous draw-off, the sap must be fed by an automatic float-operated valve, and this must work smoothly without any sticking. The larger the evaporator, the easier it is to draw off continuously; with a small evaporator, the stream of sirup is so small that it is difficult or impossible to control. The sirup draw-off valve shown at "F" in Figure 5 must be a type that can be accurately adjusted to give any desired rate of flow. A needle valve is desirable, especially for small evaporators. A globe valve or a bibcock, if it has a fixed (nonpivoting) disk, may be used for larger evaporators; it must be of the slow-opening type. The valve should be located at least 3 inches below the bottom of the sirup pan, or lower if possible. It should not be so large that is will be open only a very little way when sirup is being drawn off. The principal difficulty in operating is a natural tendency to turn the sirup valve too far when readjusting it.

It is of the greatest importance to be able to measure accurately the strength of the sirup just coming to the draw-off valve. The partitions in the sirup pan, especially near the outlet, must be carefully designed to avoid dead pockets and eddies and to prevent partly concentrated sirup from mixing with the sirup being drawn off and thus causing erratic fluctuations in its density. The use of a hydrometer for measuring the density of the sirup as it is being drawn off introduces an undesirable lag, because the hydrometer cannot register the true density of the sirup in the pan until

this sirup displaces the contents of the chamber in which the hydrometer is floating. The density of the sirup collected after drawing off should, however, be checked occasionally by a good hydrometer, especially whenever the smoothness of operation has been disturbed by putting fresh sap of different density or different temperature into the same storage tank from which the evaporator is being fed. Measuring the temperature of the boiling sirup just before it leaves the pan, by means of an accurate thermometer, is almost a necessity in controlling the density of a continuous draw-off, because it tells at a glance the strength of the sirup before it is drawn off. The most useful type of thermometer is one that has a movable scale or dial, to compensate for the altitude of the sugarhouse and for daily variations in the barometric pressure. Every morning, or oftener if the barometer is changing rapidly, the thermometer is plunged into the sap at the place where it first boils, and the scale is then adjusted so that the needle stands at the point marked "Water Boiling", or 212° F. Replaced in its proper place to measure the temperature of the sirup, it will then read exactly 7° above the "Water Boiling" mark when the sirup is of correct density. A dial thermometer of this kind, designed by Dr. Charles O. Willits and made by the Rochester Manufacturing Company, Rochester, New York, (1) was used in these experiments. It is shown at "G" in Figure 5.

COSTS

Cost of Equipment: Although costs of installation and operation will vary widely according to the size of the evaporator and local conditions, a few approximate figures may be of interest. For example, to evaporate 200 gallons of sap per hour (which, allowing for the increased capacity obtained by oil-firing, might be done by an evaporator 48" by 12' - 0" or 14' - 0"), the oil burner itself, including motor and switches, but not installation, would cost about $300 to $350. Smaller burners would not be a great deal cheaper. The brick for the entire furnace and evaporator could be purchased for about $230, and a 3000-gallon oil storage tank for about $350; these two items would cost less for a smaller evaporator. To these figures must be added the costs of electric wiring, oil piping, installation, foundations, etc. The entire cost would probably run to $1000 or $1500, if the foundations, installation, piping, and wiring were done by a contractor. If this work can be done by farm labor, the total expense will of course be less.

Cost of Operation: Under the assumptions given below, the costs of operation are approximately the same for oil-firing as for wood-firing (Table1). The evaporator will handle 2000 gallons of sap per 10-hour day, and burn 200 gallons of oil. For No. 2 oil at 13 cents per gallon, this amounts to $26. Yearly fixed charges for interest and depreciation are assumed to be 10 percent of the investment (2). On this basis, if the installed cost of the burner, arch, and oil tank is $1200, the fixed charges are $120 per year. As an approximation, it may be assumed that the evaporator operates for 15 days in the year. The fixed charges for the oil-burning will then be $8 a day, which added to $26, the cost of the oil, gives a total of $34 a day, regardless of how much sirup is made from the 30,000 gallons of sap.

TABLE I

Approximate Costs to Evaporate 2000 Gallons of Maple Sap per 10-hour Day
Oil versus Wood

	Oil	Wood
Cost of fuel delivered at the sugarhouse	26.00	29.00
Interest and depreciation on oil-burning equipment	8.00	---
Cost of labor for firing	---	5.50
Total cost per day (approximate)	$34.00	$34.50

The average cost of wood fuel to produce 1 gallon of sirup has been reported for three regions for the year 1947. The figures are based on the market value of the wood at each farm, which ranged from $5 to $15 per cord. For 20 farms in New York State (2), the average was 40 cents per gallon of sirup; at the sugarbush of the Michigan Experiment Station (4) it was 38 cents; for 49 farms in Ohio (3), the average was about 44 cents. Of course, the figure varies widely between different farms according to the value of wood there, but for an approximation we may take the average for these 70 sugarbushes (20 at 40 cents, 1 at 38 cents and 49 at 44 cents), which is 43 cents, not including the cost of labor for firing the wood. The average for the 49 Ohio farms showed that about 43 gallons of sap was required to make a gallon of sirup; this is a good approximation for other localities as well. The cost of wood fuel per gallon of sap will then be one forty-third of 43 cents, or 1 cent, and the cost per day for evaporating 2000 gallons, will be $20. These are all 1947 figures. The average wage of labor has increased 45 percent since then and it can safely be assumed that the value of wood has increased proportionately. The wood may therefore be valued at $29 per day. To this must be added the labor cost of handling the wood from the shed to the arch, and the cost of firing. Although the evaporator operator with some assistance from the sap-gatherers may in some cases be able to handle this, it is done at the expense of other work such as weighing and canning. The total of such labor may easily amount to more than half of one man's time. In 1947 wages in the New York area averaged 75 cents an hour. An increase of 45 percent would bring this to $1.09. Five hours of a 10-hour day at $1.09 an hour, or about $5.50, would bring the total cost of wood-firing to $34.50 a day, or practically the same as the $34 per day for oil-firing.

The actual costs will vary with the size of the evaporator and the conditions of operations, as well as with the value of the fuel. But aside from actual costs of fuel and firing, the maple sirup producer should consider the other advantages of oil; less soot, no ashes, better scheduling because of constant evaporation rate, and most important of all, more uniform and probably better sirup.

LITERATURE CITED

(1) Anonymous, "New Thermometer Simplifies Maple Sirup Production", Energy, Ed. II, v. 14, no. 3 May-June 1952. (Published by Energy Control Co., New York, N. Y.)

(2) Bond, A. Dewey, "Costs and Returns in Producing Maple Syrup, 20 Farms, New York, 1947", Cornell Univ., Dept. Agr. Econ. and Farm Managt., Farm Econ., A.E. 661, 13 pp., 1948. (Processed.)

(3) Moore, H. R., Baker, R. H., and Diller, O. D., "The Farm Sugar Bush", Ohio Agr. Expt. Sta., Farm and Home Research 33 (no. 251), 40-45, 1948.

(4) Robbins, Putnam W., "Production of Maple Syrup in Michigan", Mich. Agr. Expt. Sta. Cir. Bul. 213, 28 pp., 1949.

(5) Willits, C. O., Porter, W. L., and Buch, M. L., "Maple Sirup. V. Formation of Color During Evaporation of Maple Sap to Sirup", Food Research 17, 482-486, 1952.